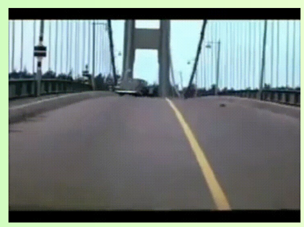
Waves	Stationary waves and harmonics

Learning objectives	MUST (6)	Explain the formation of a stationary wave, and distinguish it from a progressive wave
	SHOULD (7)	Understand that stationary waves only form at certain frequencies, and the meaning of a harmonic
	COULD (8/9)	Identify the harmonics of given waves, and use them to calculate wave characteristics

STARTER: This is real footage of a bridge which (unsurprisingly) collapsed in 1940. Look at its movement. Are there any spots on which it would be safer to stand? Where?



EXTENSION: What do you think caused this? This bridge was unusual for the time - it had rigid sides, not an open lattice structure. How did this contribute to the problem?

'Tubby' the dog: the only casualty

Waves	**Stationary waves and harmonics**
MUST (6)	Explain the formation of a stationary wave, and distinguish it from a progressive wave

A stationary wave occurs when two waves with the same frequency travel in opposite directions. Constructive and destructive inferference occurs when the waves are in phase and antiphase. Because the waves have the same frequency, the positions of constructive/ destructive inferference are always at the same places.

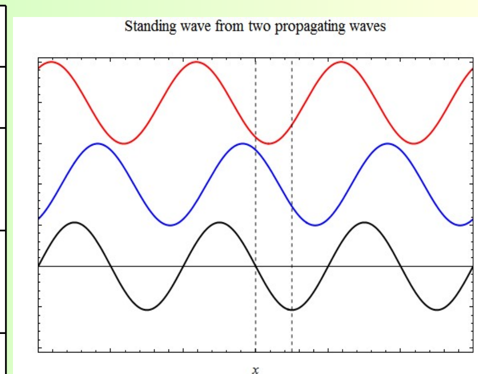
Destructive interference: **nodes** - points of zero displacement

Constructive interference: **antinodes** - points of maximum displacement

https://ophysics.com/w3.html

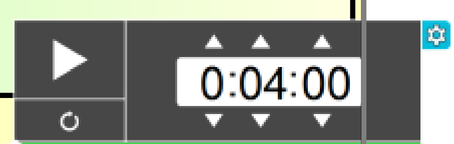
Complete the table:

	Progressive	Stationary
Is energy transferred?	Yes	No
Do all particles have the same amplitude?	Yes - their maximum displacement is the same	No - some have a greater maximum displacement
Phase differences between neighbouring particles?	There is a phase difference between neighbouring particles	All particles between the same two nodes are in phase
Do all particles vibrate?	Yes	No - the nodes don't
Do all particles vibrate with the same frequency?	Yes	Yes (except nodes, which don't vibrate)



Extension: can you suggest a way to express the phase difference between any two points on a stationary wave?

In a stationary wave: the phase difference between two points is mπ, where m is the number of nodes between them.



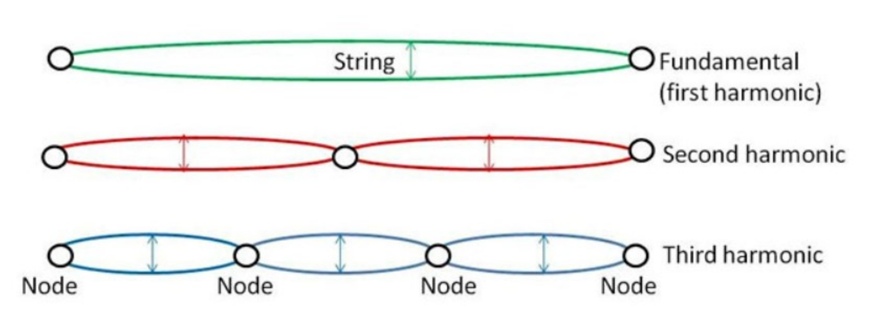
Oct 16-21:59

Waves	**Stationary waves and harmonics**
SHOULD (B)	Understand that stationary waves only form at certain frequencies, and the meaning of a harmonic

If a string is fixed at two ends, then a wave **must** have a node at each end, because the amplitude at those points must be zero.

A **harmonic** is a stationary wave. Look at the first three harmonics below, for a string fixed at each end. If the string is L metres long, what is the wavelength of each harmonic?

Now think about frequency. If the first harmonic has a **fundamental frequency** f_0 - how do the others compare? The speed of each wave is the same so $v = f\lambda$ must be constant



$\lambda = 2L$ $f = f_0$

$\lambda = L$ $f = 2f_0$

$\lambda = 2L/3$ $f = 3f_0$

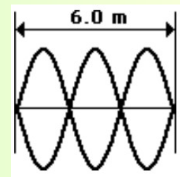
Stick in the table of harmonics that you have been given. Note that, for **two fixed ends**,

- the first harmonic is half a wavelength
- The harmonics go up in integer numbers of half-wavelengths, therefore
- the *nth* harmonic has *n* antinodes

- Recall that if the wavelength of a wave on a string is not an integer number of half-wavelengths, a standing wave won't be formed.

Waves	**Standing waves and harmonics**
COULD (A/A*)	Identify the harmonics of given waves, and use them to calculate wave characteristics

The diagram on the right represents a standing wave on a string. It vibrates 45 times in 10 seconds. Which harmonic is this? What is its wavelength, frequency and speed?



Harmonic: Third

Frequency: 4.5 Hz

Wavelength: 4.0 m

Speed: 4.5 Hz x 4.0 m = 18 m/s

0:05:00

Extension: What would the frequency be of the next harmonic?

4.5 Hz is $3f_0$, therefore 1.5 Hz is f_0. The frequency of the fourth harmonic is $4f_0$, which is 6 Hz.

A stationary wave is formed on a string of length 90 cm. At 3.6 kHz, six antinodes can be observed.

a Determine the wavelength of the progressive waves on the string.

b Calculate the speed of the progressive waves travelling along the string. *(4 marks)*

a [redacted]

b [redacted]

Waves	Stationary waves and harmonics	
Learning objectives	MUST (6)	Explain the formation of a stationary wave, and distinguish it from a progressive wave
	SHOULD (7)	Understand that stationary waves only form at certain frequencies, and the meaning of a harmonic
	COULD (8/9)	Identify the harmonics of given waves, and use them to calculate wave characteristics

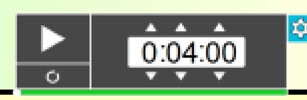
PLENARY:

The speed of waves in a particular guitar string is 425 m/s. Determine the fundamental frequency (1st harmonic) of the string if its length is 76.5 cm.

1st harmonic: $\lambda/2$.

The length is 76.5 cm, and there's half a wavelength on it; so the wavelength is 1.53 m.

$v = f\lambda$, and so $f = v/\lambda$. $f = 425/1.53 = 278$ Hz.



Oct 16-21:59